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This grant provided funding for the purchase of a low-noise, two-velocity-component flow measurement system.

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A Final Report on

MULTI-AXIS, 3-D, SCANNING LDA SYSTEM FOR UNSTEADY AERODYNAMICS

GRANT NUMBER AFOSR-87-0014

From

Air Force Office of Scientific Research
Bolling Air Force Base
Washington D. C. 20332

by

WILLIAM S. SARIC
Professor

Mechanical and Aerospace Engineering
Arizona State University
Tempe, AZ 85287-6106

December 1989

ABSTRACT

This the final report on AFOSR Grant AFOSR-87-0014 With the funds provided by this grant, a low-noise, two-velocity-component flow measurement system was developed. It consists of a two-color Laser-Doppler anemometer and a two-channel hot-wire system. The system is operational and is now being used for DoD supported research.

TABLE OF CONTENTS

1. INTRODUCTION

A Laser Doppler Anemometer (LDA) system and a low-noise hot-wire anemometer system to measure simultaneously the two components of velocity in the neighborhood of surfaces was assembled with the funds provided by the referenced grant ($148,965.77) and by additional Arizona State University cost sharing of 34.6% ($51,615.43). The system includes standard 2-color, 2-velocity component LDA optical hardware (tabulated in section 2.2), a Spectra Physics Model 2016, Argon-Ion Laser operating at 8 watts , a traversing mechanism, two-channels of DANTEC low-noise hot wire anemometers, AT-type computers as interfaces, and an existing data acquisition computer. Thus a variety of two-dimensional (2-D) and three-dimensional (3-D) flow fields can be mapped.

The original proposal requested funds for two independent laser systems that would be assembled for direct 3-D measurements (hence the title contains the words: multi-axis, 3-D). However, the funds were not available for this more extensive system. The research team is satisfied that the AFOSR grant provided the basic hardware package to begin 2-D LDA measurements. The system continues to be improved by the introduction of fiber optics units, laser sheet optics, forward-scatter measurements, and scanning using other sources of funding. The completed system will have the following capabilities.

(i) Single-Point Measurements of 3-D Flow Fields. Very accurate two-velocity-component measurements can be made in problems of mean-flow distortion and secondary instabilities due to unstable stationary streamwise vortices, afterbody separation, flow fields near wing-root junctions, and 3-D fluctuations in transitional and turbulent boundary layers.

(ii) Scanning Measurements in 3-D Flow Field. Under unsteady conditions or in cases of dynamic stall it is desirable to have a fast scan of the velocity profile. By using recently developed *scanning LDA* technology, almost-simultaneous velocity profile measurements can be made. Based on the work of Chehroudi and Simpson scanning frequencies of 150 Hz are feasible. However, with the fast A/D of the MASSCOMP Data Acquisition System, the time lag problems of previous investigators are avoided. Hardware is now being designed to affect the scanning.

(iii) Perpendicular-Plane Measurements and Forward-Scatter Measurements. Designs have just been completed to have an alternate set of optics in order to transmit the laser beam in a plane perpendicular to the one presently used. This will not only

provide the capability to obtain the third velocity component but to orient the sample volume parallel to the body so that its diameter (111 μm) is the critical dimension within the boundary layer rather than its length (1.25 mm).

An essential part of this instrumentation is the use of the existing computers and advanced optics being developed at Arizona State University (ASU) to enhance the data-acquisition capabilities of the LDA and advance the state-of-the-art. The computer/data acquisition system is described in Reference 1. This system will be used in the ASU Unsteady Wind Tunnel (also described in Reference 1).

2. EQUIPMENT

2.1 General Description

The purchase of the equipment listed in section 2.2 below was funded by the AFOSR Grant. The equipment listed in section 2.3 was funded by the Arizona State University cost-sharing. The photographs shown on pages 16-17 of Reference 2 illustrate the laser system in operation.

2.2. Revised List of Equipment and Budget-AFOSR

2.2.1 Two-Color Laser Doppler Hardware and Optics

This unit consists of: Collimators, Color Filters and Polarization Rotors,#9108, #9159, #9102-11; 2 adjustable Beam-Splitters, #9115-1; Beam Displacer, #9174; 2 Frequency Shifters,#9180-12; 2 Receiving Optics, #9140 4,410; 2 Photomultipliers, #9160; Scattered Light Color Separator, #9145; Beam Steering & Adjusting Modules, #9175; Beam Expanders (3.75x), #9189; Dispersion Color Separator, #9105; 2 Counters and Signal Processor, #1980-B; 2 Readout Modules,#1992; Lens, 750mm focal length, #9169-50; Beam Splitter and Stepper, #9115, #9181-4; Eye Pieces, Micro Objectives, and Optics Kits, #10096, #10092, #10097-A; Traversing Mechanism (stepping motors, servos, rotating mirrors, etc.) #9400; Atomizer, #9306;

SUB-TOTAL 2.2.1 with discounts $101,241

The source of the equipment was TSI, Inc., St. Paul, MI 55164. The model numbers refer to TSI equipment.

2.2.2 Argon Ion Laser

This unit is a model 2016 Argon-Ion laser capable of operating at 8 watts continuous. The laser was purchased from Spectra Physics.

SUB-TOTAL 2.2.2 with discounts $24,901

2.2.3 Two Component, Low Noise, Hot-Wire Anemometer

This unit consists of: 2 Main Anemometer Units incl. accessories #55M01; 2 Power Packs incl. accessories #55M05; 2 CTA Bridges #55M10; 2 Cable Compensation Kits incl. 20m cable #55M85; 2 Frames #52A22; 1 Linearizers #55M25; 1 top plate.

SUB-TOTAL 2.2.3 with discounts $17,822

Model numbers refer to DISA equipment. Equipment purchased from: DANTEC Electronics Inc., Allendale, N.J. 07401.

2.2.4 Signal Analysis Unit

This unit consists of: 3 Differential Amplifiers w/Power Modules *Tektronix* Models #AM502, #TM503

SUB-TOTAL 2.2.4 with discount $4,601

2.2.5 Computer Support Equipment

This is an Epson FX-86 Printer

SUB-TOTAL 2.2.5 with discount $401

AFOSR TOTALS **$148,966**

2.3 Revised List of ASU Cost-Shared Equipment

This list of equipment consists of: 1 Dual Phase-Lock Amplifier, *Stanford Research* Model #SR530; 1 Function Generator, *Kron-Hite* Model #2200; 1 8-Channel Oscilloscope, *Tektronix* Models #5440, #5A14N, #5B42; 6 Digital Multimeters, *Fluke* models #8050A, #8050A-01; 1 6-Pen Plotter, *Hewlett-Packard* model #HP7475-001; 2 Power Supplies, 40v/15a, 300v/2a, *EM Inc.* models #TCR40315, #TCR30052; 2 *Tandon* AT 2861 computers; 1 *Epson FX-86 printer; 1 DANTEC* rms voltmeter; 1 *TSI* model 9302, laser particle generator; 1 *Seiko* A size color hard copier.

ASU TOTAL 2.3 **$51,615**

In addition to the listed cost sharing, ASU has already provided $300,000 for the assembly of the Unsteady Wind Tunnel, a new dedicated 3,375 sq ft building within which the proposed LDA system is housed, and the MASSCOMP Data-Acquisition System (see Reference 1).

2.4 Inventory Records

Table 1, shown on the next page, contains the inventory records of all of the equipment. In the accounting procedure of ASU, all of the costs of all of the equipment, regardless of their original designation as AFOSR equipment or ASU cost shared equipment, were put together and paid on a 74.3%/25.7% AFOSR/ASU split. Moreover, only the AFOSR costs are listed under "value" on the inventory records.

The equipment lists and costs given in sections 2.2 and 2.3 follows more closely with the equipment request of the original proposal.

INVENTORY OF PROPERTY
ARIZONA STATE UNIVERSITY
TEMPE, ARIZONA

SPONSOR: AFOSR DATE: 5/11/89
AWARD NO: 87-0014 ASU ACCOUNT NO: XAA 1715/EQ FINAL X OTHER __

ASU/AGENCY ID#	DESCRIPTION OF ITEM	SERIAL NO.	TITLE	VALUE
6034764	COMPONENTS FOR UNSTEADY WIND TUNNEL	NONE	ASU	29,809.59
6037296	DANTEC RMS VOLTMETER (LESS $90.20 CASH DISCOUNT)	2076	ASU	2,949.80
6042546	TANDON AT 286I MICROSOFT MOUSE	17450	ASU	1,859.33 83.96
6042255	TANDON AT 286I MICROSOFT MOUSE	17450	ASU	1,859.33 83.96
6042886	EPSON FX-86 PRINTER	P0009792	ASU	245.76
6042887	EPSON FX-86 PRINTER	P0009802	ASU	245.76
6044770	ARGON ION LASER	140	ASU	18,500.00
6047736	PARTICLE GENERATOR, MODEL 9302	NONE		577.51
6043966	LASER DOPPLER ANEMOMETER	NONE	ASU	75,215.98
6049519	SEIKO A SIZE COLOR HARD COPIER	NONE	ASU	7,526.00
6049522	SEIKO REMOTE COPY START SWITCH SEIKO VIDEO SIGNAL ADAPTER	NONE	ASU	162.00 700.00
6049523	SEIKO VIDEO SIGNAL ADAPTER	NONE	ASU	700.00
	INSTALLATION OF SEIKO HARD COPIER			638.00
	STRAIGHT MOUNTING TUBE			30.00
	CHUCK			50.95
	PROBE SUPPORTS			495.00
	GUIDE TUBE			50.00
	SENSOR SHORTING PROBE			80.00
	TAX			7,057.84
				148,965.77

The undersigned contractor, having completed the work called for by Contract Number 87-0014, hereby certifies that all materials, supplies, and equipment which were furnished to the contractor or has been or will be reimbursed by AFSOR under the terms of the contract, if not specifically included in the foregoing inventories, were expended in the performance of the contract.

CONTRACTOR: Arizona State University

PREPARED BY: Steve Reding 5/11/89
Steve Reding
Property Administrator

3. RESEARCH PROJECTS

3.1 Enhancement of Currently Funded DoD Research

"Three-Dimensional Structure of Transitional Boundary Layers," AFOSR-F49620-85-C-0089, 15 Jun 85 - present.

PI: William S. Saric.

In this task, detailed experiments and analytical/numerical methods are combined for investigating selected topics that are crucial for a deeper understanding of laminar-turbulent transition and of turbulent flows. First, the three-dimensional flow field and the high-frequency phenomena at breakdown are analyzed to reveal the interaction of large-scale structures, small-scale components, and the viscous sublayer Second, the effects of freestream disturbances due to sound and background turbulence on stability characteristics and transition are studied. These effects are key to the receptivity problem in laminar flows as well as to the self-sustaining turbulence after formation of the laminar sublayer. By using combined flow visualization, hot-wire anemometry, and the LDA system with the in-house developed advanced optics and pulsed particle entrainment in the wind tunnel, the ideal *measurement triad* will be complete.

3.2 Enhancement of Research of Interest to DoD

"Transition Studies on a Swept-Wing Model," NASA-Langley Research Center, Grant No. NAG-1-937 1 Oct 88 - present.

PI: William S. Saric.

This project is concerned with the stability and transition of three-dimensional boundary layers that are characteristic of swept-wing flows. Particular attention is paid to crossflow instabilities and the subsequent transition process. The experimental techniques are directly related to the ongoing AFOSR work and as such are very complementary.

4. REFERENCES

1. Saric, W. S. "The ASU Unsteady Wind Tunnel", *ASU CEAS Tech. Rpt. CR-R 89030*, April 1989.
2. Storad, C. J. ed. "Arizona State University Research", Summer 1988, pages 16-19.